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# How To
# Identify and Manage Dutch Elm Disease

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## Cover photo

Advanced symptoms of Dutch elm disease on a large American elm in Minnesota. USDA Forest Service photo by Linda Haugen.

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# How To

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## Contents

## Introduction

The American elm was once considered an ideal street tree because it was graceful, long-lived, fast-growing, and tolerant of compacted soils and air pollution. Then Dutch elm disease (DED) was introduced and began devastating the elm population (figure 1). Despite staggering losses, elm continues to be a valued component of the urban forest because it is so well-suited to urban environments. The goal now is to save remaining large elm and choose suitable replacement trees for the ones that cannot be saved.

This guide provides urban foresters, tree care practitioners, and land managers with updated DED information and available management options.

Figure 1.—Historic photograph captures the typical devastation Dutch elm disease inflicted on neighborhoods. Once a tree in a row is infected, the disease can move through connected root systems to kill the entire row. Courtesy photo by Dr. R. Jay Stipes, Virginia Polytechnic Institute and State University.

## Symptoms

DED symptoms develop when a fungus infects the vascular (water-conducting) system of the tree. Once infected by the fungus, vascular tissues become clogged—preventing water movement to the crown and causing visual symptoms as the tree wilts and dies.

### Foliage symptoms.

DED symptoms begin with wilting leaves and proceed to yellowing and browning. The pattern of symptom progression within the crown varies depending on where the fungus is introduced to the tree. If the fungus enters a tree through roots grafted to infected trees (see disease cycle section), the symptoms may begin in the lower crown on the side nearest the graft and rapidly affect the entire crown. If the fungus initially infects the upper crown, symptoms often first appear at the end of that individual branch (called "flagging") and progress downward into the crown (figure 2).

Figure 2.—Branch flagging symptoms from a single point of Dutch elm disease infection in the crown of an elm. Courtesy photo by Dr. R. Jay Stipes, Virginia Polytechnic Institute and State University.

Multiple branches may be individually infected, causing a tree to develop symptoms at several locations in the crown (figure 3). Symptoms begin in late spring or any time later during the growing season. However, if a tree was infected the previous year (and not detected), symptoms may be observed in early spring. Symptoms may progress throughout the whole tree in a single season or may take two or more years.

Figure 3.—Branch death, or flagging, at multiple locations in the crown of a diseased elm. USDA Forest Service photo by Dr. Steven Katovich.

### Vascular symptoms.

Branches and stems of elms infected by the DED fungus typically develop dark streaks. To detect discoloration, cut through and peel off the bark of a dying branch to expose the outer rings of wood. In newly infected branches, brown streaks characteristically appear in the current year sapwood (figure 4). Cutting deeply into the wood or cutting a cross section of the branch is important for two reasons: (1) as the season progresses, unstained wood may grow over the dark streaking, and (2) if infection occurred in the previous year, the current sapwood may not be discolored.

Figure 4.—Brown streaking develops in sapwood of branches infected by the Dutch elm disease fungus. Streaking is visible here (from left to right) in: (1) the newly formed sapwood, (2) springwood sapwood overlaid by uninfected summer wood, and (3) is absent in an uninfected branch. Photo courtesy of the American Phytopathological Society.

## Distinguishing Dutch Elm Disease from Other Problems

Other pest problems commonly observed on elm include leaf spot diseases (cause dark spots of dead tissue in the leaves) and elm leaf beetles (eat holes in the leaves), which are easily distinguished from DED due to their different signs/symptoms. Several fungal pathogens also cause death of main stems and individual branches by causing cankers under the bark tissue. Dieback from cankers may resemble DED (flagging or whole tree death), but will usually show visible cankering/damage to the bark below the affected/symptomatic limb or stem/trunk.

Two other diseases, elm yellows and bacterial leaf scorch, are more easily confused with DED. The symptoms of these diseases are compared to DED in table 1.

### Elm yellows.

This disease, which is also called elm phloem necrosis, is caused by a phytoplasma (microscopic bacteria-like organism) that systemically infects the phloem tissue (inner bark) of the tree. It is a serious disease that causes tree death. Foliage symptoms of elm yellows differ from DED in that the leaves turn yellow (not brown and wilted) and drop prematurely, and they appear simultaneously throughout the entire crown. Elm yellows doesn’t change sapwood color (no brown streaking like DED), but produces a tan discoloration in the inner bark and a characteristic wintergreen odor.

### Bacterial leaf scorch.

This disease is caused by the bacterium *Xylella fastidiosa* subspecies *multiplex*, which infects and clogs the water conducting tissues of the tree. Infection by this bacterium causes a slow decline over many years. Once a tree is infected, symptoms recur annually. The symptom of scorch is an irregular browning along the

leaf margin with a yellow border between green and scorched leaf tissues. Older leaves on a branch are affected first.

**Table 1.—Comparison of symptoms of three elm diseases.**

| Dutch Elm Disease | Elm Yellows | Bacterial Leaf Scorch |
|---|---|---|
| Initially affects individual branches OR affects lower crown nearest root graft. | Affects the entire crown. | Damage initially observed on single branches, and spreads to entire crown; oldest leaves affected first. |
| Leaves wilt and turn yellow, then brown. | Leaves turn yellow and may drop early. | Leaves brown along margin, with a yellow halo on the inside. |
| Symptoms often observed in early summer but may be exhibited any time of the growing season. | Symptoms visible from July to September. | Symptoms appear in summer and early fall. |
| Brown streaking in sapwood. | No discoloration in sapwood. | No discoloration in sapwood. |
| No discoloration in inner bark. | Tan discoloration in inner bark. | No discoloration in inner bark. |
| No wintergreen odor. | Wintergreen odor in inner bark. | No wintergreen odor. |

## Disease Cycle of Dutch Elm Disease

The biology, or "disease cycle," of DED depends upon the host, the fungus, and the way the fungus enters the new host tree (figure 5).

### The elm host.

Native species of North American elms vary in susceptibility to DED, even within species. American elm (*Ulmus americana* L.) is generally highly susceptible. Winged elm (*U. alata* Michx.), September elm (*U. serotina* Sarg.), red elm (U. rubra Muhl.), rock elm (*U. thomasii* Sarg.), and cedar elm (*U. crassifolia* Nutt.) range from susceptible to somewhat resistant. No native elms are immune to DED, but some individuals or cultivars have a higher tolerance (and may recover from or survive with infection) or resistance to DED. Many European and Asiatic elms are less susceptible than American elm.

In addition to genetic factors present in some cultivars and species, physical factors affect tree susceptibility. These factors include time of year, climatic conditions (such as drought), and vitality of the tree. Water conducting elements are most susceptible to infection as they are developing in the spring, thus elms are most vulnerable after earliest leafing out to midsummer. Trees are less susceptible under drought conditions. Vigorously growing trees are generally more susceptible than slower growing trees.

### The Dutch elm disease fungus.

In the U.S., DED is caused by either of two closely related species of fungi: *Ophiostoma ulmi* (Buism.) Nannf. and *Ophiostoma novo-ulmi* Brasier (more aggressive at causing disease). Elm logs from Europe carried the DED fungus *O. ulmi* to the U.S. prior to 1930. It is unknown when the more aggressive species became established in the U.S.—possibly as early as the 1940s or 50s—*O. novo-ulmi* most likely caused much of the devastating elm mortality during the

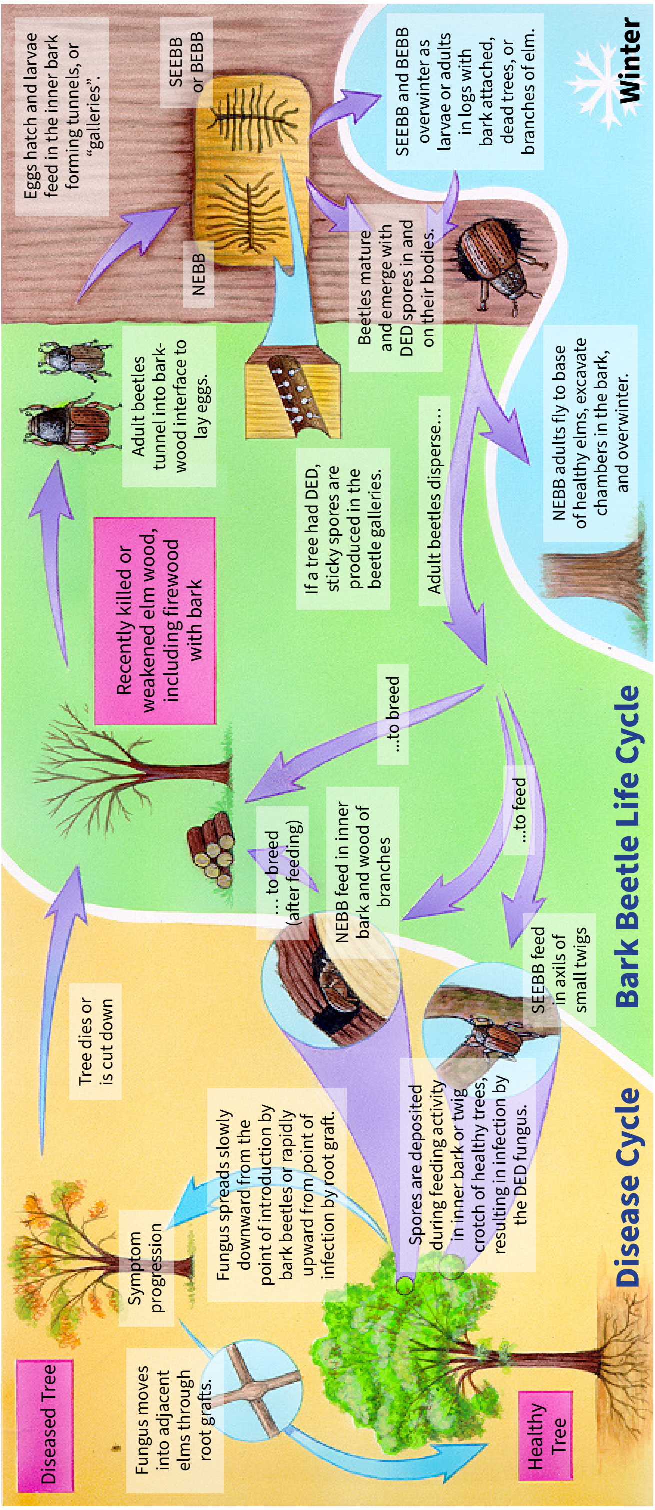


Figure 5.—The disease cycle of Dutch elm disease is closely linked to the life cycles of elm bark beetles. *In the graphic, SEEBB = Smaller European elm bark beetle | BEBB = Banded elm bark beetle | NEBB = Native elm bark beetle.* USDA Forest Service graphic created under contract by Julie Martinez, Scientific Illustrator, St. Paul, MN.

1970s. The less aggressive species is now rare in nature, while the aggressive species is thought to be responsible for most of the current mortality. Although some local resurgence of DED has been observed, no evidence indicates a change in the pathogen. Localized resurgence is more likely due to: (1) decreased vigilance in monitoring and sanitation, (2) a build-up of insect vector populations, or (3) growth of elms into a susceptible size class.

## Spread by elm bark beetles.

Overland spread of DED is closely linked to the life cycles of the native elm bark beetle (*Hylurgopinus rufipes* Eich.) and the smaller European elm bark beetle (*Scolytus multistriatus* Marsh.) (figure 6). A


Figure 6.—Overland spread of DED is closely tied to the life cycles of the native elm bark beetle (top), smaller European elm bark beetle (middle), and banded elm bark beetle (lower). Note that the smaller European elm bark beetle is actually larger than the native elm bark beetle.
USDA Forest Service artwork of banded elm bark beetle by Juliette Watts; USDA Forest Service artwork of native and smaller European elm bark beetles created under contract by Julie Martinez, Scientific Illustrator, St. Paul, MN.

third potential vector, the banded elm bark beetle (*S. schevyrewi* Semenov) was detected in North America in 2003 but may have been present for much longer. The banded elm bark beetle is now widely distributed across the U.S.; its life cycle and feeding habits are similar to the smaller European elm bark beetle. The banded elm bark beetle has demonstrated vectoring capability for the DED pathogen, but evidence to date indicates it is no more effective than the smaller European elm bark beetle.

All three species of elm bark beetles seek stressed and dying elm trees, or dead elm wood, to complete the breeding stage of their life cycle. Adult beetles tunnel into the bark and lay eggs in tunnels (called galleries) in the inner bark. When the eggs hatch, the larvae feed in the inner bark and sapwood.

The larvae mature into adults before emerging from the elm wood. If the wood is infected with DED fungus, the fungus produces sticky spores in the beetle galleries. The beetles eat the fungal spores, or the spores stick to the adult beetles as they emerge from diseased trees. Adult beetles then visit healthy trees and introduce the fungus into or near injured wood vessels as they feed.

As vectors of DED, the three bark beetle species vary in importance across the range of elms. In northern areas (northern parts of Minnesota, Wisconsin, Maine, New York, and New England and most of Canada; where winter temperatures below –6 °F are common), the native elm bark beetle is the predominant vector. In other parts of North America, the smaller European elm bark beetle predominates — except where displaced by the banded elm bark beetle, such as in the Rocky Mountain region. The life habits of the native elm bark beetle adults differ considerably from the other two species. These differences are described below and have implications for management opportunities

Smaller European elm bark beetles and banded elm bark beetles overwinter as larvae or adults within the tree stem where they hatched. The adults emerge in spring to feed in twig crotches of healthy trees, where they can introduce spores of the DED fungus to the crown. High numbers of beetles frequently will feed in a single tree, resulting in multiple points of infection. The cycle is repeated when beetles then seek out diseased and dying wood to breed in throughout the growing season, completing two or more generations per year. They have the potential to rapidly build up high populations.

Adult native elm bark beetles tunnel into the bark on the lower stems of healthy elms to overwinter. In spring they emerge to feed in the inner bark of elm branches and small stems before beginning their breeding cycle. They repeat their life cycle as previously described. They can transmit the DED fungus to healthy trees during the construction of overwintering sites in fall, or, more commonly, during feeding in spring.

Once the DED fungus is introduced into the upper crown of healthy elms by bark beetles, it moves downward, killing the branch as it goes. Disease progression may occur rapidly, killing the tree by the end of the growing season, or may progress gradually over a period of two or more years. It is also possible the tree may recover. The success and rate of progression within the tree depends on tree size, timing and location/site of infection, climatic conditions, and host tree response.

## Spread through grafted roots.

Roots of the same or closely related tree species growing near each other often cross each other in the soil and eventually fuse together (become grafted).

The DED fungus can move from infected trees to adjacent trees through these grafted roots. Infections through root grafts can spread rapidly throughout the tree, as the fungus is carried upward in the sap stream. In urban areas where elms are closely spaced, DED spread by root graft is a significant cause of tree death (figure 7).

Figure 7.—Dutch elm disease fungus moved down a row of closely spaced street trees through grafted roots. Removing diseased trees without breaking root grafts may not keep the fungus from moving into adjacent trees. USDA Forest Service photo by Dr. Joseph O'Brien.

## Managing Dutch Elm Disease

DED is managed by interrupting the disease cycle. The most effective means of breaking the cycle is early and thorough sanitation to limit the population of the insects that transmit the fungus from tree to tree. Other useful tactics include using insecticides to kill the insect vector, breaking root grafts between trees, injecting individual trees with fungicides to prevent or halt the fungus, pruning out early infections, and planting DED tolerant or resistant elm species and varieties or other tree species.

### Sanitation to reduce insect vectors.

Many communities have maintained a healthy population of mature elms through a vigilant program of identification and removal of diseased elms and systematic pruning of weakened, dying, or dead branches. Sanitation by prompt removal of diseased trees or branches reduces breeding sites for elm bark beetles and eliminates the source of the DED fungus. To be completely effective in interrupting the spread of the disease by elm bark beetles, stems and branches of DED infected trees must be debarked, destroyed, or utilized before the bark beetles emerge. During the growing season, removal should be completed within 2 to 3 weeks of detection. During the dormant season, removal should be completed before April, when overwintering beetles may begin to emerge.

Wood from infected trees can be destroyed by chipping, burning, or burying. Wood may be retained for use as firewood or sawlogs if it is debarked or covered during the growing season (roughly from April 15th to October 15th) with 4 to 6 mil plastic (note that these dates are approximate and may differ outside of the upper Midwest region). The edges of the cover must be buried or sealed to the ground. If it is impossible to destroy all elm wood before the beetles emerge, the wood can be sprayed with a registered insecticide until disposal is possible. If insecticides

are used, consider potential exposure to chemical residues when burning or handling the treated wood. Many communities have regulations on the removal of diseased elms and storage of elm firewood; make sure your activities comply with local regulations.

## Insecticides to kill insect vectors.

In areas where the native elm bark beetle is the principal vector, sanitation may be augmented by applying a registered insecticide to the lower stem of healthy elms in late summer to early fall (i.e., at the first sign of autumn leaf color change) to kill adult beetles as they prepare overwintering sites.

In areas where the smaller European elm bark beetle are common, spring feeding in twig crotches can be prevented by spraying the crowns of elm trees with a registered insecticide. However, this treatment method may not be ideal due to difficulty getting thorough coverage of all susceptible twig tissue, the risk of insecticide drift and exposure, and high expense.

Insecticide registrations and recommendations are frequently updated and may vary considerably between states. Land-grant University Cooperative Extension programs and certified arborists can provide current insecticide recommendations.

## Disruption of root grafts.

Large trees within 25 to 50 feet of each other are likely to have root grafts. Breaking root grafts between infected trees and adjacent healthy trees is an important means to prevent fungus movement into the healthy trees. Root grafts should also be disrupted between the healthy tree adjacent to a diseased tree and the next healthy tree. It may even be desirable to sever grafts between very valuable trees before DED is observed in the vicinity, as a proactive measure.

Before removing infected trees, disrupt root grafts to healthy trees. Otherwise, severing the stem of the diseased tree releases the vascular tension on the

roots, and allows the transpirational pull of the healthy tree to rapidly draw in the contents of diseased tree's root system.

Disrupt root grafts using a vibratory plow or any trenching machine equipped with the longest blade available (preferably 5 feet long, but at least 3 feet long). Biocidal soil fumigants may also be used to kill root grafts if no other alternatives are available. However, these chemicals are generally restricted use pesticides and may only be applied by professional pesticide applicators. In addition, biocidal chemicals may not be effective if soil temperatures are below 50 °F.

## Injecting elms with fungicide.

Certain fungicides, when properly injected, are effective in protecting elm trees from infection via beetle transmission. This treatment is expensive and must be repeated every one to three seasons, thus it is appropriate only for high value or historically important trees. The treatment itself also may pose risks to the health of the tree.

To be effective, the fungicide must be at adequate concentration at all potential points of infection. Thus, the dosage and means of application are critical to success. The injection of chemical into healthy root flare tissue in large volumes of water (macroinjection) provides thorough distribution of chemical in the crown (figure 8). Microinjection (injection of small

Figure 8.—Macroinjection of fungicide into the root flare of an elm tree. Courtesy photo by Mark Stennes, St. Paul, MN.

volumes of concentrated chemical) is also an option, although the fungicide is less likely to be effectively distributed throughout the tree canopy due to the smaller volumes.

Fungicide injections should be done soon after the earliest leaves have fully expanded but may be done from then to the end of the growing season. Label rates of concentration for chemical application are updated to reflect the most recent findings on effectiveness; always follow the current label.

Harmful effects of fungicide injection have been reported and include occasional leaf “scorching” or loss. Phytotoxic effects are more prevalent under extreme heat or drought, but watering following treatment can help ameliorate the damage. Phytotoxicity is more common when treating red elm (*U. rubra*) than American elm, so a lower chemical rate may be used. Drilling injection holes results in wounding, which, if repeated annually, may eventually result in significant discoloration and decay. Following fungicide injection with a flush of clean water can reduce damage to the cambium. Some chemicals can protect trees for up to three seasons, thus minimizing the frequency of treatments.

Several fungicides are registered for injection to prevent DED infection. These chemicals vary in duration of protective effects, means of application, risk of damage to the tree, documentation of effectiveness, and cost. Protection of high-value mature elms generally requires a repeated 2-3-year injection cycle. Certified arborists or Cooperative Extension programs at Land-grant Universities can provide current recommendations on product availability and effectiveness.

## Eradicating Dutch elm disease from newly infected trees.

If a new crown infection of DED is detected early

enough, there is opportunity to save a tree through pruning, fungicide injection, or both. Eradicative treatment is not appropriate for trees infected via root graft transmission. Pruning, which can literally eradicate the fungus from the tree, has a high probability of "saving" a newly infected tree that has less than 5% of its crown affected. To be a candidate for eradicative pruning, the infection must be a new infection (not a residual infection from the previous season) and be present only in the upper crown (not yet present in the main stem). Since infection may be more advanced than symptoms indicate, it is important to peel off the bark of infected branches and locate the staining, which indicates the presence of the fungus. All infected branches should be removed at a branch fork at least 5 feet, and preferably 10 feet, below the last sign of streaking in the sapwood (figure 9). When DED is confirmed or suspected in younger or smaller DED-resistant trees, complete removal of infected branches showing streaking may not be possible. While there is no research that supports this practice, practitioner evidence suggests that removal of symptomatic branches in small trees of

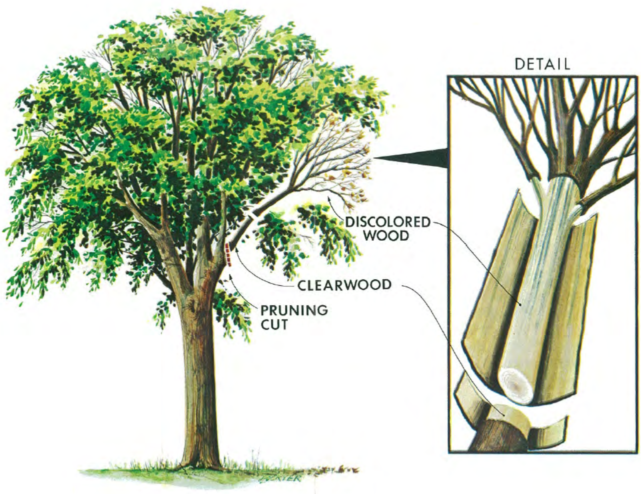


Figure 9.—Eradicative pruning of DED-infected branches may be effective if there is an adequate length (5 to 10 feet) of clearwood between the infected tissue and the remainder of the crown, or if the tree has been properly treated with fungicide. USDA Forest Service artwork by Jim Lockyer.

resistant species and varieties may enhance survival, even when crown symptoms exceed 5%.

Pruning is more likely to be effective if augmented by systemic injection of fungicides. Proper use of fungicides eliminates the need to eradicate all infected tissues from the tree, although all dead branches should eventually be removed. Whereas pruning alone is not effective against residual infections, fungicide injection may be. If fungicides are used, they should be injected **prior** to removal of diseased branches. The keys to successful eradicative treatment are early detection and prompt treatment.

## Planting Dutch elm disease resistant trees.

Planting DED-resistant elms is a valid management option, however these trees still require active management. Resistance is not immunity, and even trees with a high level of resistance may succumb to DED when they face high disease pressure or other factors that allow the disease to prevail. Mature disease resistant elms should not require the rigorous 2-3-year fungicide injection cycle for protection, but should still be monitored and treated if they become infected with DED.

Some DED-resistant American elm cultivars require a significant amount of pruning to achieve a structurally sound mature form (figure 10). Whenever elm branches are pruned during the growing season, pruning paint specifically formulated for use on trees should be applied to prevent attraction of elm bark beetles to the wounded trees. (Painting tree wounds is generally not recommended, except to prevent disease transmission in oaks and elms.)

Planting a diverse mixture of elm species and varieties is prudent, since selecting only a few types of elms limits the genetic variability of the population. This could lead to increased risk of widespread losses if

those selected for planting are found to be susceptible to tree health problems such as poor adaptation to site, air pollution, other elm pests or pathogens, or other strains of DED which may eventually develop.

Finding resistance to DED in American elm has been slow and discouraging, as early screening found little evidence of resistance. Haugen and Bentz (2017) were aware of only eight named commercially available clones of American elm with demonstrated levels of resistance to DED, some of which have poor growth form or other undesirable characteristics. More

Figure 10.—With some American elm cultivars, extensive pruning may be necessary to achieve a structurally sound mature form. Courtesy photo by Chad Giblin, Trees and Me, Inc., St. Paul, MN.

options may become available soon, as elm selection programs have many additional clones in various stages of testing. Research on progeny from known resistant elms has demonstrated at least some forms of resistance are heritable. In addition, after over 50 years of repeated waves of DED infections, large survivor elms persist in the wild, indicating they may have some level of resistance. With this information, additional clones are being collected for evaluation. Many of these clones may be used in breeding populations to produce elm seed with enhanced resistance for restoration plantings.

Besides true American elms, there are many other species, commercially developed hybrids, and selections of elm that have high tolerance or resistance to DED. Several of these have attractive form, are well suited to urban environments, and are readily available. Note that few of these other species will present the classic American elm form. In particular, the introduced species are often much smaller at maturity.

In addition to a diverse selection of elm types, location and spacing are important considerations to reduce losses from DED. When selecting landscape trees and their locations, plant a mixture of tree species appropriate to the site. In addition to species diversity, consider tree spacing. By carefully selecting planting location and maximizing tree species diversity, future root graft problems can be avoided.

## Trees in Natural Stands or Wild Areas

Infected elms in wild areas and natural stands that are within or near urban areas often serve as a reservoir of elm bark beetles and DED fungus to infect high-value landscape trees. Management is necessary to protect urban elms and sanitation is the most effective option. Promptly removing stressed, dead, and dying elms as previously described reduces both bark beetle vectors and the DED fungus. However, this intensity of treatment is often not feasible.

Another option in wild areas or natural stands, other than accepting losses from DED, is eliminating all elms and managing for alternative species. However, retaining elms is often desirable for biodiversity, and aesthetic, economic, or other reasons. In riparian areas where the viability of green and black ash has become threatened by emerald ash borer, retaining American elm as a forest component has been become increasingly important.

## Deciding Which Management Practices to Use

Different management strategies will be applicable depending on whether you are working with a community program or trying to protect individual trees. In a community program, the objective will be to protect a population of elms within the community boundaries. Individual landowners may want to protect or save their own elms but will have no control over what neighbors do with trees on their property. The amount of money an individual or community is willing to invest will influence which management practices to implement.

Where you have no control over the management of surrounding trees, fungicide treatments may be the most effective option to protect or save individual trees. Good sanitation practices and disruption of root grafts will still be necessary on an individual property, but these practices alone will not protect a tree from disease carried by bark beetles over property lines. Preventive fungicide injection, eradicative pruning and fungicide injection, and insecticide treatment are generally the only viable options available to protect individual trees.

In a community program, resources to spend on individual trees may be low, but managing populations of elms presents greater opportunity. Where there are continuous elms, root graft disruption is essential to halt the spread. Sanitation is key to reducing bark beetle and DED populations and is effective. Communities can establish ordinances to encourage prompt removal of diseased trees and prevent storing elm wood with bark intact. Education will help citizens understand the importance and benefits of working together to manage DED. As resources allow, use preventive and eradicative treatments, and

insecticides to augment a program. If a community has a significant elm resource, consult the literature in the following section to learn what has worked well in other communities.

In wildland settings, the focus will be on retaining elms that persist and adding resistance through planting. Retaining large elms that have survived previous DED waves increases the chances of preserving existing DED resistance in the elm population (figure 11). When augmenting the elm population, use the best available seed or seedlings for site adaptation as well as resistance. Distribute the elm component throughout the stand, with individual stems spaced far enough apart to minimize likelihood of root grafting.

Although DED has had a massive impact on our forests, elms should and will continue to be a component of many urban and rural forests. As landowners and communities consider what trees will compose the future forest they can learn from the past and carefully choose the types of trees and where to plant them.

Figure 11.—This large American elm in northern Minnesota has persisted on the landscape despite long-term exposure to Dutch elm disease. “Survivor elms” like this one may be a source of resistance to Dutch elm disease. USDA Forest Service photo by Linda Haugen.

# References and Relevant Literature

Allison, J.R.; Gregory, G.F. 1979. How to save Dutch elm diseased trees by pruning. NA–GR–9. [Leaflet]. [Broomall, PA]: U.S. Department of Agriculture, Forest Service. [Not paged].

Ascerno, M.E.; Wawrzynski, R.P. 1993. Native elm bark beetle control. FS–01420–GO. St. Paul, MN: University of Minnesota Extension Service, Communication and Educational Technology Services. http://cues.cfans.umn.edu/old/extpubs/1420ebb/DG1420.html. [Accessed: July 30, 2023].

Brasier, C.M. 1991. *Ophiostoma novo-ulmi* sp. nov., Causative agent of current Dutch elm disease pandemics. Mycopathologia. 115: 151–161. https://doi.org/10.1007/BF00462219. [Accessed: July 30, 2023].

Giblin, C.; Johnson, G. 2019. Dutch elm disease-resistant elm trees. University of Minnesota Extension. https://extension.umn.edu/trees-and-shrubs/dutch-elm-disease-resistant-elm-trees#sources-1657210. [Accessed March 2023].

Hanisch, M.A.; Brown, H.D.; Brown, E.A., eds. 1983. Dutch elm disease management guide. Bulletin One. [Place of publication unknown]: U.S. Department of Agriculture, Forest Service and Extension Service; final phase; National Dutch elm disease demonstration program. 24 p. In cooperation with: State agencies of California; Colorado; Georgia; Minnesota; Wisconsin.

Haugen, L.M.; Bentz, S.E. 2017. American elm clones of importance in Dutch elm disease tolerance studies. In: Pinchot, C.C.; Knight, K.S.; Haugen, L.M. [and others], eds. Proceedings of the American elm restoration workshop 2016. Gen. Tech. Rep. NRS–P–174. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station: 109–118. https://www.fs.usda.gov/research/treesearch/54952. [Accessed: July 30, 2023].

Jacobi, W.R.; Koski, R.D.; Negron, J.F. 2013. Dutch elm disease pathogen transmission by the banded elm bark beetle *Scolytus schevyrewi*. Forest Pathology. 43(3): 232–237. https://doi.org/10.1111/efp.12023. [Accessed: July 30, 2023].

Pinchot, C.C.; Knight, K.S.; Haugen, L.M. [and others], eds. 2017. Proceedings of the American elm restoration workshop 2016. Gen. Tech. Rep. NRS–P–174. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 148 p. https://doi.org/10.2737/NRS-GTR-P-174. [Accessed: July 30, 2023].

Stennes, M.A.; French, D.W. 1987. Distribution and retention of thiabendazole hypophosphite and carbendazim phosphate injected into mature American elms. Phytopathology. 77(5): 707–712. https://doi.org/10.1094/Phyto-77-707. [Accessed: July 30, 2023].

Stipes, R.J.; Campana, R.J., eds. 1981. Compendium of elm diseases. St Paul, MN: American Phytopathological Society. 96 p.

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